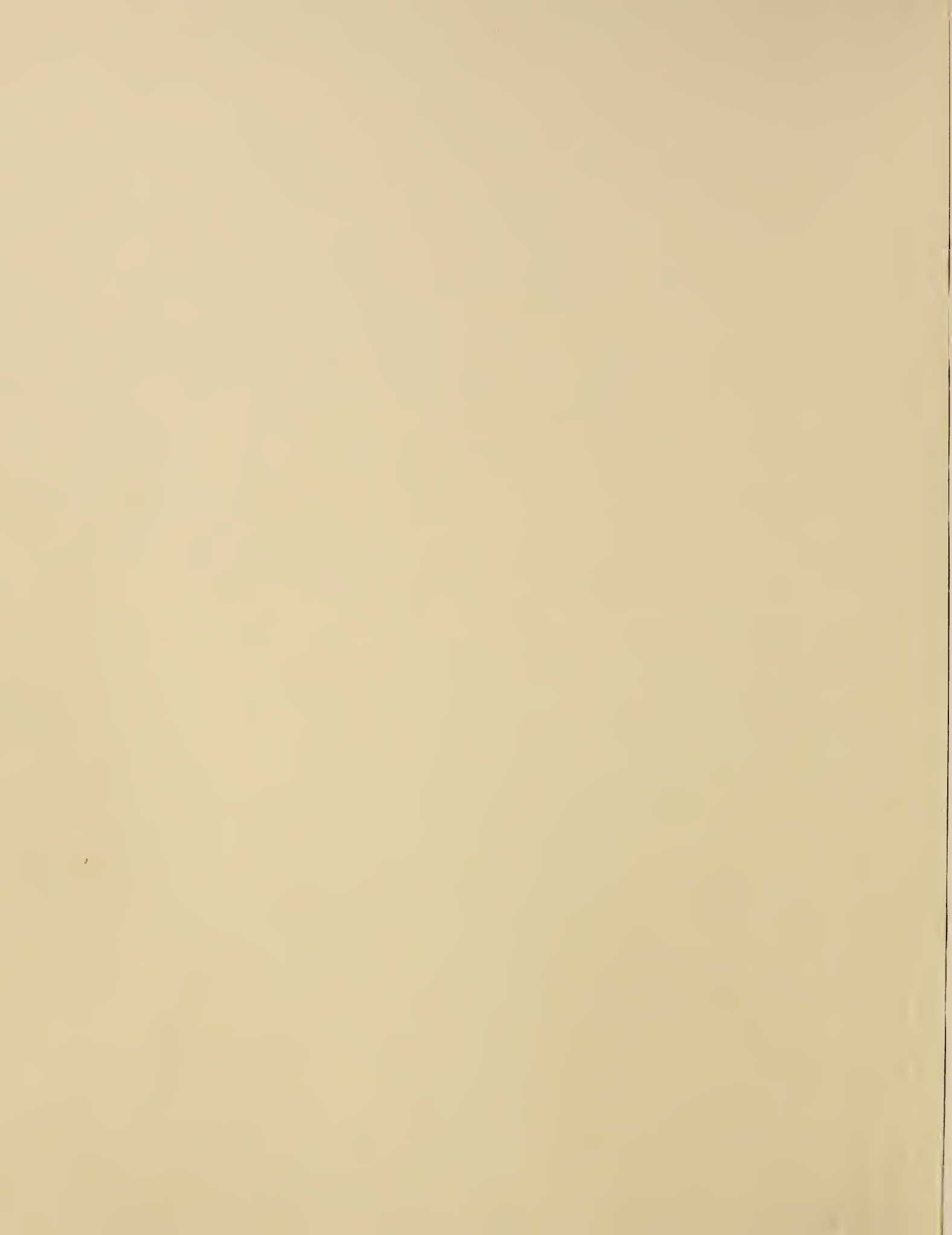


Historic, Archive Document

Do not assume content reflects current scientific knowledge, policies, or practices.



A 58.9

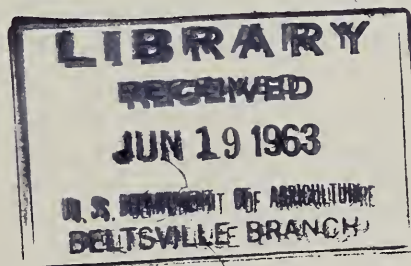
R 31

ARS 42-82

ARS 42-82

May 1963

SPRAY DISTRIBUTION PATTERNS FROM
A STEARMAN AIRPLANE FLYING AT 50 FEET



Agricultural Research Service
UNITED STATES DEPARTMENT OF AGRICULTURE

CONTENTS

	Page
Equipment and procedure -----	2
Results -----	6
Spray deposits from front and rear booms --	6
Spray deposits from left and right halves of the boom -----	8
Spray deposits from outboard quarters and standard boom -----	11
Spray deposits from inboard half and standard boom -----	13
Spray deposits from inboard third and standard boom -----	16
Spray deposits from flow rates of 16.7 g.p.m. (100-foot swath) and 21.4 g.p.m. (132-foot swath) -----	18
Typical deposit graph from flights with a Stearman at 50 feet -----	20
Summary and conclusions -----	21
Recommendations -----	22

ACKNOWLEDGMENTS

The authors gratefully acknowledge the assistance of Dorothy Thornton Drooz, the late J. M. Davis, J. P. Secrest, J. M. Miller, and other personnel of the Beltsville Forest Insect Laboratory in conducting the flight tests and dye tracer determinations.

SPRAY DISTRIBUTION PATTERNS FROM A
STEARMAN AIRPLANE FLYING AT 50 FEET 1/

By D. A. Isler and J. S. Yuill 2/

In some of the early work with aerial spraying immediately following World War II, it became apparent that discharging the spray at different points across the wingspan of an airplane could produce a marked difference in the pattern of the spray swath deposited on the ground. In most instances, however, it was not possible to determine how much of the effect was due to nozzle location and how much to difference in atomization or other factors. Since the swath pattern has an important relation to the coverage and ultimate effectiveness of the application, specific studies soon were initiated to determine the arrangement of outlets or nozzles that would give the most uniform distribution.

Chamberlin and associates in Oregon 3/ and Roth in Texas 4/ investigated the swath patterns produced in the low level flights (usually up to 10 feet) employed in treating crops. During the same period, similar investigations were being carried out at the Agricultural Research Center, Beltsville, Md., on the spray patterns produced at the higher flight levels (about 50 feet) and lower application rates used in treating forests. This paper describes the Beltsville investigations that dealt with the effect of nozzle location on spray distribution.

-
- 1/ Based on work carried out jointly by Beltsville Forest Insect Laboratory, Division of Forest Insect Research, Forest Service, and Agricultural Engineering Research Division, Agricultural Research Service, U. S. Department of Agriculture.

Mention in this publication of commercially manufactured equipment and products does not imply endorsement over similar equipment and products not mentioned.

- 2/ Agricultural Engineer, Agricultural Engineering Research Division, ARS, and Entomologist, Division of Forest Insect Research, FS, respectively.
- 3/ Chamberlin, J. C., Getzendaner, C. W., Hessig, H. H. and Young, V. D., 1955. Studies of airplane spray-deposit patterns at low flight levels. U.S. Dept. Agr. Tech. Bul. No. 1110.
- 4/ Roth, G. A., 1953. Some effects of span-wise nozzle location on spray distribution (Stearman and Ag-1 airplanes). Second Ann. Tex. Agr. Aviation Conf. Papers. (Processed.)

EQUIPMENT AND PROCEDURE

The Stearman biplane trainer (PT17 or N2S) was selected for this work because it was the light airplane most commonly used in forest spraying. The particular 220-h.p. plane used was equipped with a dual spray apparatus developed by Miller and Isler ^{5/} for experimental spraying (fig. 1). Essentially, this apparatus consists of two complete and independent spray systems which permit simultaneous applications from two different nozzle arrangements as a paired test.



Figure 1 - Stearman equipped with dual spray apparatus

The idea of using a dual sprayer for comparing the effect of nozzle location on spray distribution is based on the assumption that when the two systems simultaneously deliver the same amount and kind of insecticide and when the same nozzle equipment and operational conditions are used, the resulting spray deposits should be identical.

For all these tests centrifugal-type hollow-cone nozzles with 1/8-inch orifices were used. In mounting the nozzles, they were directed forward and downward 12 degrees to the thrust line of the plane (fig. 2). Spray pressure was approximately 25 p.s.i. Under these conditions, the nozzles produced an atomized spray having an m.m.d. (mass median diameter) of approximately 150 microns, which was within the range recommended for most forest spraying.

The flow rate for each of the two spray systems in the dual sprayer was adjusted by adding or removing nozzles as required. Most flights were made with flow rates of approximately 21 g.p.m. (gallons per minute), the rate required to apply 1 g.p.a. (gallon per acre) on a swath 2 chains wide (132 feet) when the plane was flown at a speed of 80 m.p.h. There is of course the possibility that the actual flow rate at the time of the tests

^{5/} Miller, J. M., and Isler, D. A. 1951. Dual spray equipment for airplane spraying tests. U. S. Dept. Agr., Bur. Ent. and Plant Quar. ET-294.

varied slightly from the calibrated flow rate. In one series the flow rate was reduced to approximately 16 g.p.m., the quantity required to cover a swath 100 feet wide at the rate of 1 g.p.a. when the plane was flown at a speed of 80 m.p.h. All sprays were released at approximately 50 feet above the ground. This height was selected because it represents the minimum safe spraying height above the tree tops in forest spraying.



Figure 2 - Dual sprayer booms with centrifugal-type hollow-cone nozzles with 1/8-inch orifices which during flight are directed forward and down 12 degrees to the thrust line of plane.

The spray material in some of the early tests was the "standard" formulation commonly used in forest spraying: 1 pound of DDT in 1 gallon of oil (Yuill, et al., 6/). In later tests, the standard formulation was replaced by a solution containing either (1) one-half pound of DDT in 0.4 gallon of solvent (Socony-Vacuum Corp., Sovacide 544B) with No. 2 fuel oil to make 1 gallon or (2) two-thirds gallon of solvent with No. 2 fuel oil (no DDT) to make 1 gallon. These solutions had the same distribution characteristics as the standard formulation.

Separate measurements were made of the spray deposits from the two spray systems on the plane by the dye tracer method. An orange dye (Calco Oil Orange 7/) at the rate of 5 pounds per 100 gallons of spray was placed

6/ Yuill, J. S., Eaton, C. B., and Isler, D. A. 1951. Airplane spraying for forest pest control. U.S. Dept. Agr., Bur. Ent. and Plant Quar. E-823.

7/ Manufactured by American Cyanamid Co.

in one system, and a blue dye (Alizarine Irisol ^{8/} or National Brilliant Oil Blue ^{9/}) at the rate of 2 pounds per 100 gallons of spray was placed in the other system.

All flights were made over a special test area on open ground (fig. 3). Four sampling lines, each 600 feet long and oriented to the cardinal compass directions, were placed on the area. The center of each line was a common point. Stakes 3 feet high were set at 5-foot intervals along each line for sampling points. A spring clip was attached to the top of each stake to hold two 6 X 6-inch flat aluminum plates (each with several hammer dents to keep them from sticking when stacked) for collecting the falling spray and one 3 X 5-inch white file card as a visual indicator of the distribution across the line (fig. 4).

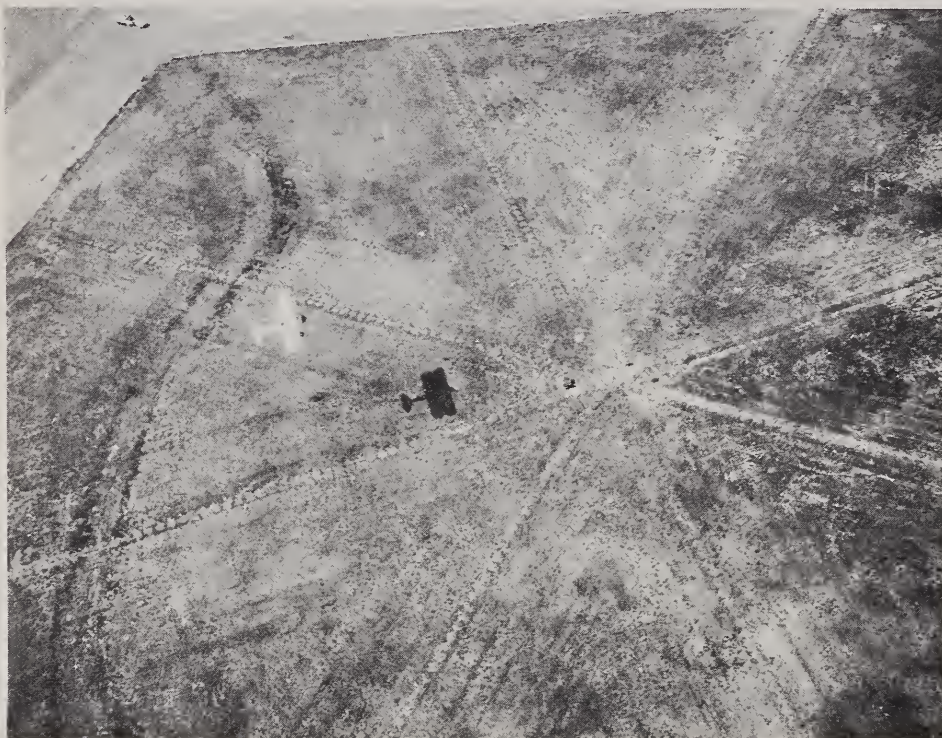


Figure 3 - Test area at Beltsville airport.
Four 600-foot sampling lines.

All test flights were made early in the morning or during late evening when air movement was least. Most of the flights were made when wind velocities were less than 5 m.p.h. and when a stable or inversion gradient of temperature existed between heights of 5 and 50 feet above ground. All flights were made as nearly as possible into the wind. To apply the spray, the pilot flew a straight and level course across the test area. Both sprayer systems

^{8/} Manufactured by General Analine and Film Corp.

^{9/} Manufactured by Allied Chemical and Dye Corp.

were turned on when the plane approached to within 500 feet of the test area and they were left on until it reached a point at least 1,000 feet beyond the area.



Figure 4 - Two aluminum plates and one paper card for sampling spray deposit.

Yellow weather balloons inflated to a diameter of about 24 inches were used as markers to guide the pilot. In all, three balloons were used. Two of these were set 40 feet apart at the center point of the sampling lines. The third was placed directly upwind about 300 feet from the center point. The balloons were tied to 50 feet of light fishline. Smoke flares and the lean of the balloon strings were used to determine the wind direction. As the wind shifted, the position of the upwind balloon was changed. In making the spray run, the pilot flew between the two balloons at the center and over the one placed 300 feet upwind.

After each flight the spray was allowed to settle for 10 minutes before samples were collected. The line selected for sampling was the one most nearly perpendicular to the line of flight. The aluminum plates bearing spray deposits were collected from the portion of this line receiving spray, as revealed by the dye markings on the white cards. To transport the plates, the upper surfaces of each pair were turned together and the two were then stacked in a special carrying box. In the laboratory, the deposits on the two plates from each location on the line were washed off with an acetone spray and combined to form a single sample. The amount of dye in each sample was then measured in a spectrophotometer.

The spectrophotometer measurements were converted into gallons of spray per acre and the data plotted as a deposit curve. In flights where the angle between the sample line and the line of flight was greater than 15°, the 5-foot interval between sampling points was corrected to the true right angle distance by the formula:

$$i = 5 (\sin \phi)$$

where i = corrected interval distance

ϕ = acute angle between flight line and sample line

The effects of the following boom and nozzle arrangements were compared:

1. Front and rear boom
2. Left half of one boom and right half of the other boom
3. Outboard quarters and standard nozzle arrangement
4. Inboard half and standard nozzle arrangement
5. Inboard third and standard nozzle arrangement

A sixth series of tests was conducted to compare reduced flow rate (18 nozzles) with standard flow rate (24 nozzles).

Comparisons of the spray deposits from the various tests were made on the basis of uniformity of distribution across the swath, the width of swath at various deposit levels, and the percentage of the spray released from the plane that was recovered on the ground. The swath width at various deposit levels was measured from the deposit graphs. The percentage of spray recovered was calculated by the formula: (Quantity of spray deposited divided by quantity of spray released) X 100 = percent recovery.

RESULTS

Spray deposits from front and rear booms

Spray deposits from front and rear booms were compared to determine whether spray from the two booms carrying a similar nozzle arrangement produced similar distribution patterns. The arrangement of nozzles on the two booms is shown in figure 5.

The two arrangements are not identical. With one boom in front of the other it was necessary to offset the nozzles on the rear boom one spacing inboard from those on the front boom so that the spray from the two booms would not mix. The distance between nozzle outlets on the booms was 4-1/4 inches, which was the offset distance between nozzles on the rear boom as compared to the front boom.

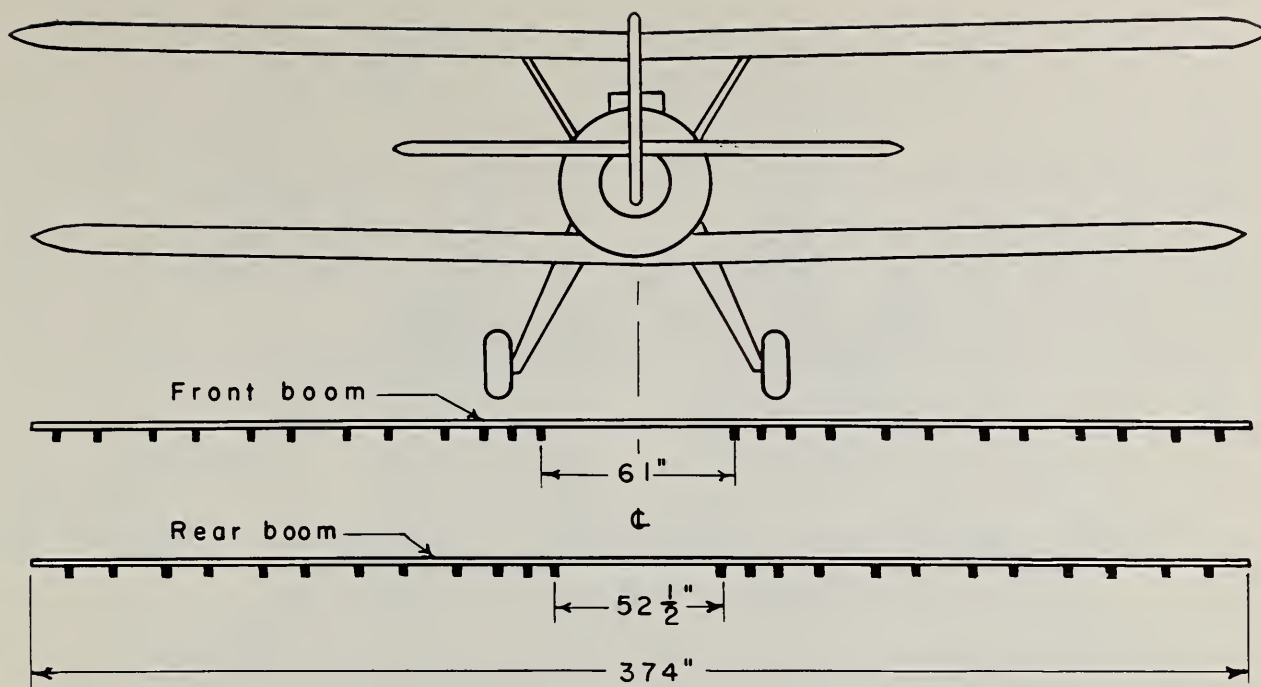


Figure 5 - Nozzle arrangement for flights comparing spray deposit from front and rear booms.

Two test flights were made. Figure 6 shows the spray distribution across the swath for one flight. The pattern of spray distribution was essentially the same for the two booms. The flow rate from the front boom was 0.7 g.p.m. more than that from the rear boom, which could account in part for the higher deposit curve for the front boom 40 to 45 feet left of the flight line.

There was very little difference in the average width of swath at various deposit levels from front and rear booms, as shown by the following tabulation for the two flights:

<u>Deposit level</u>	<u>Swath width (feet)^{1/}</u>	
<u>g.p.a.</u>	<u>Front boom</u>	<u>Rear boom</u>
0.1	155	161
.2	126	127
.3	114	113
.4	105	103
.5	82	80

^{1/} Distance over which deposit level was not less than that given in the left column.

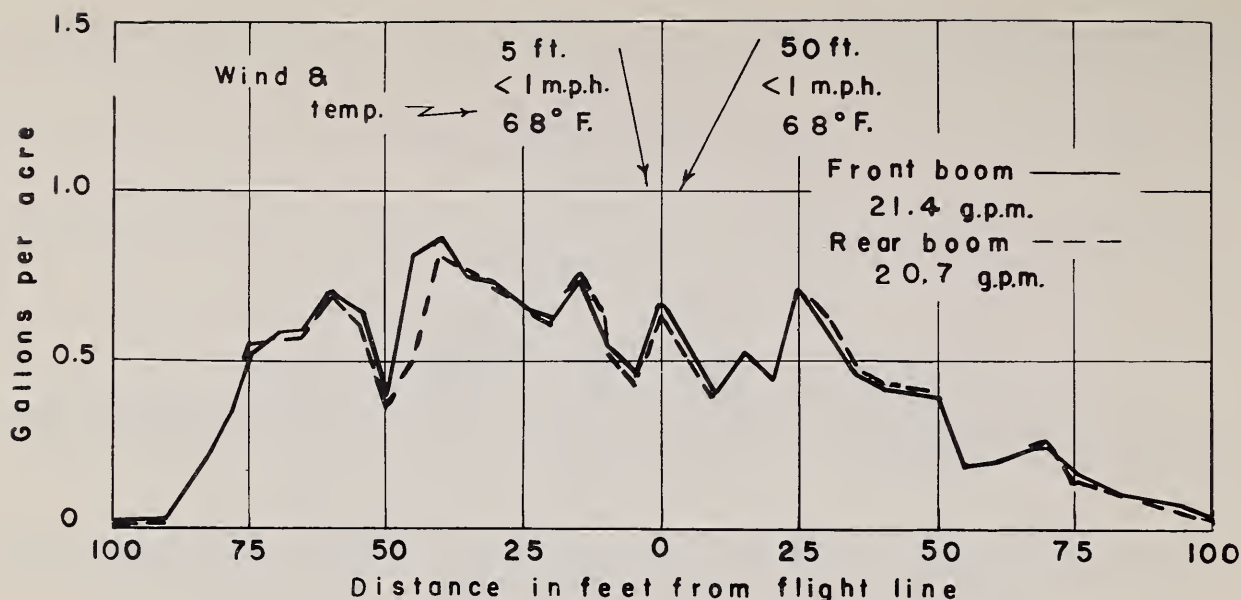


Figure 6 - Spray distribution from front and rear booms.

The spray released from the plane and recovered on the ground averaged 64 percent from each boom for the two flights. Thus, differences between deposit patterns from the two booms were not great enough to prevent use of the dual sprayer for comparing such things as two nozzle locations, two flow rates, or two spray atomizations.

Spray deposits from left and right halves of the boom

The spray deposit from the nozzles on the left half of the front boom was compared with that from the nozzles on the right half of the rear boom. All other nozzles were removed and the outlets plugged. Three flights were made.

The distribution of spray across the swath from one of the flights is shown in figure 7. The wind shifted the spray slightly to the left. Both the right and left peaks of deposit are approximately the same height.

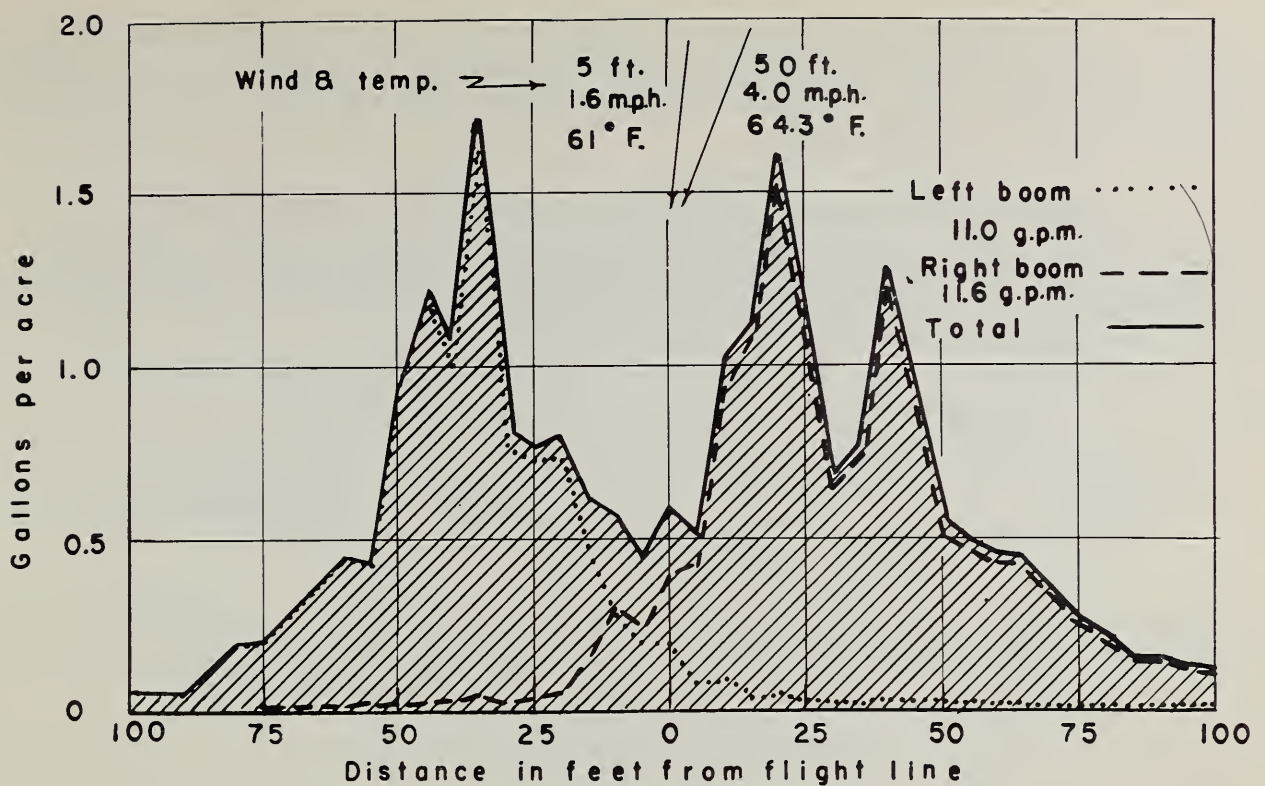


Figure 7 - Spray distribution from left half of the front boom and right half of the rear boom.

Except for the swaths at the 0.1-g.p.a. level there was on the average very little difference in swath width at various deposit levels from the two boom halves, as shown by the following tabulation of averages for the three flights:

<u>Deposit level</u>	<u>Swath width (feet)^{1/}</u>	
<u>g.p.a.</u>	<u>Left half</u>	<u>Right half</u>
	<u>of boom</u>	<u>of boom</u>
0.1	92	103
2	77	76
3	65	65
4	51	53
5	43	45

^{1/} Distance over which deposit level was not less than that given in the left column.

In two flights, percentage of spray recovery was higher from the right half boom than from the left half. In the third, the reverse was true. Average for the three flights was 82 percent from the left half, and 88 percent from the right half.

Distribution of the spray deposit was studied by dividing the swath into sections (fig. 8), and by measuring the area in each section under the deposit curve with a planimeter. From these measurements the percentage of spray volume in each section was computed (table 1).

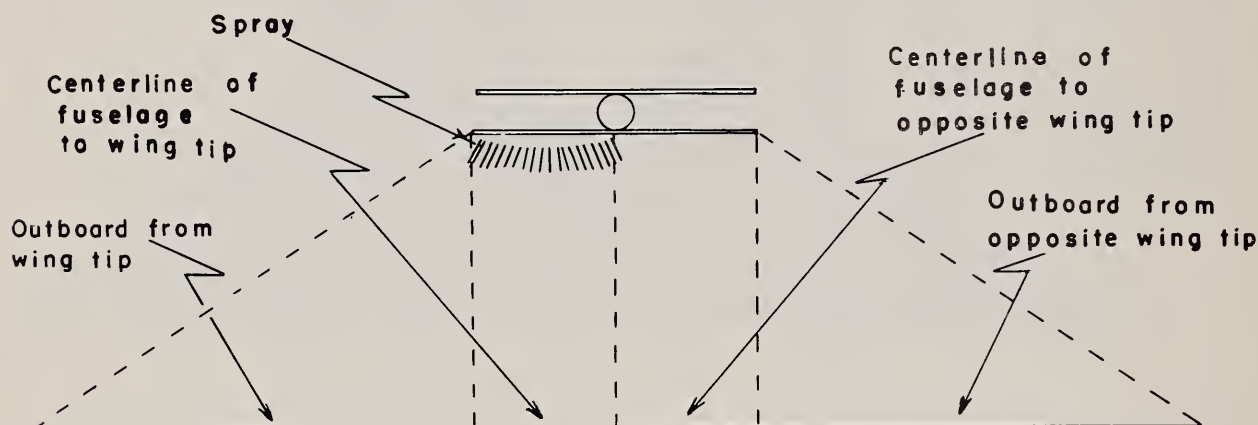


Figure 8 - Sections of spray swath - left half of boom.

Table 1. Distribution of spray volume with respect to the plane when the plane was flown at heights of 40 to 50 feet.

Flight and boom half	Distribution of spray across swath			
	Outboard from wingtip	Centerline of fuselage to- Wingtip Opposite wingtip		Outboard from opposite wingtip
	Percent	Percent	Percent	Percent
1 Right	73	18	6	3
Left	85	8	3	4
2 Right	68	16	8	8
Left	78	15	4	3
3 Right	73	18	4	5
Left	62	27	8	3
Average Right	72	17	6	5
Left	75	17	5	3

About three-fourths of the spray was deposited outboard from the wingtip when the spray was released from a height of 40 to 50 feet. Some of the spray from either the left or right half boom was distributed across practically the entire swath width.

Spray deposits from outboard quarters and standard boom

One of the objectives of studying spray deposits from various nozzle arrangements was to determine whether the characteristically abnormal high peaks that usually occur about 70 feet apart in the spray swath could be reduced and the total swath widened. One boom of the dual sprayer was equipped with a standard full wingspan nozzle arrangement and the other with varying nozzle arrangements. The arrangement of nozzles used on the two booms for a comparison of spray deposits from outboard quarters and standard boom is shown in figure 9.

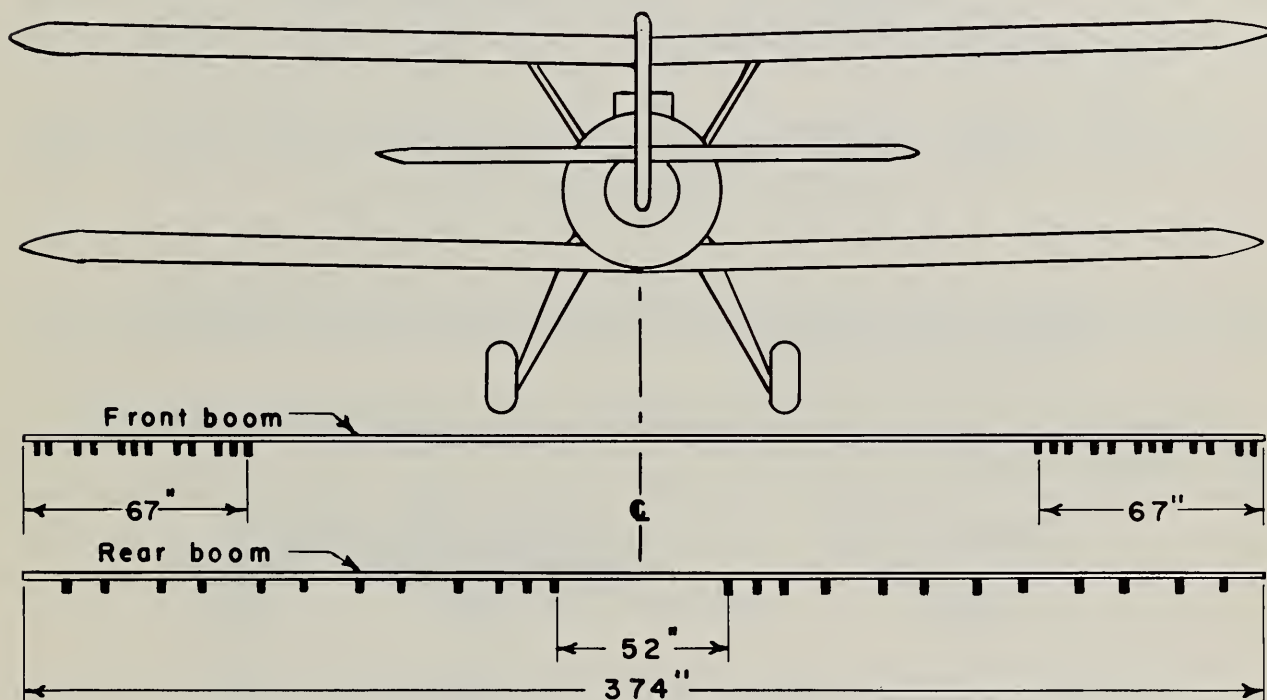


Figure 9 - Nozzle arrangement for flights comparing spray deposits from outboard quarters with that from standard boom.

Two flights were made for this comparison. The distribution curve for one flight is shown in figure 10; the other flight had the same pattern. Even though the distribution curves for both flights showed considerable effect of crossdrift, the outboard arrangement clearly deposited much higher peaks than did the standard boom. Such overdosing would be very undesirable.

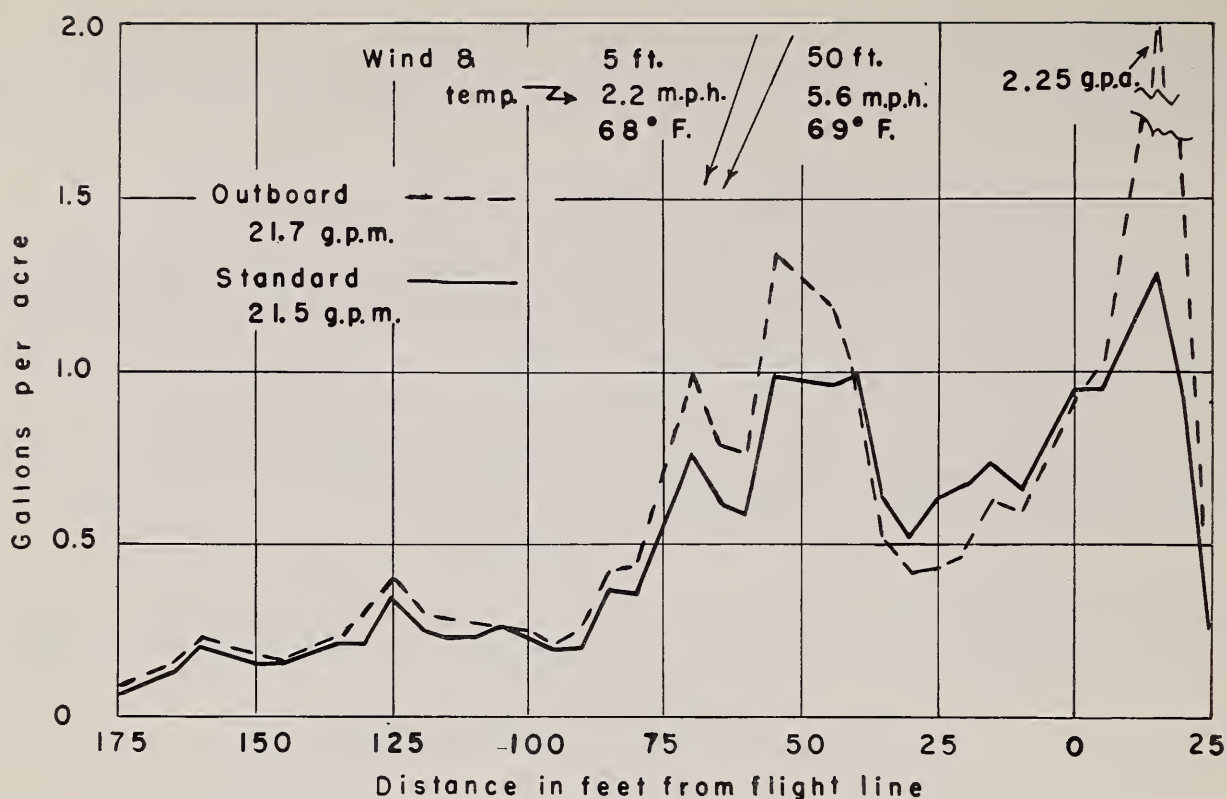


Figure 10 - Spray distribution from outboard quarters and standard nozzle arrangements.

There was no appreciable difference in the width of swath at the lower deposit levels:

<u>Deposit level</u> g.p.a.	<u>Swath width (feet)</u> ^{1/}	
	<u>Outboard quarters</u> <u>of boom</u>	<u>Standard</u> <u>boom</u>
0.1	190	188
.2	139	137
.3	110	107
.4	100	96
.5	84	91

^{1/} Distance over which deposit level was not less than that given in the left column.

Spray recovery was 82 percent from the nozzles on the outboard quarters of the boom and 72 percent from those on the standard boom.

Spray deposits from inboard half and standard boom

Tests comparing spray deposits from inboard half and standard boom were in two parts: In one set of tests, 24 nozzles were used, giving a flow rate of 1 g.p.m. over a 132-foot swath and 4 flights were made; in the second set, 18 nozzles were used, giving a flow rate of 1 g.p.m. over a 100-foot swath and two flights were made. The nozzle arrangements for these flights are shown in figure 11.

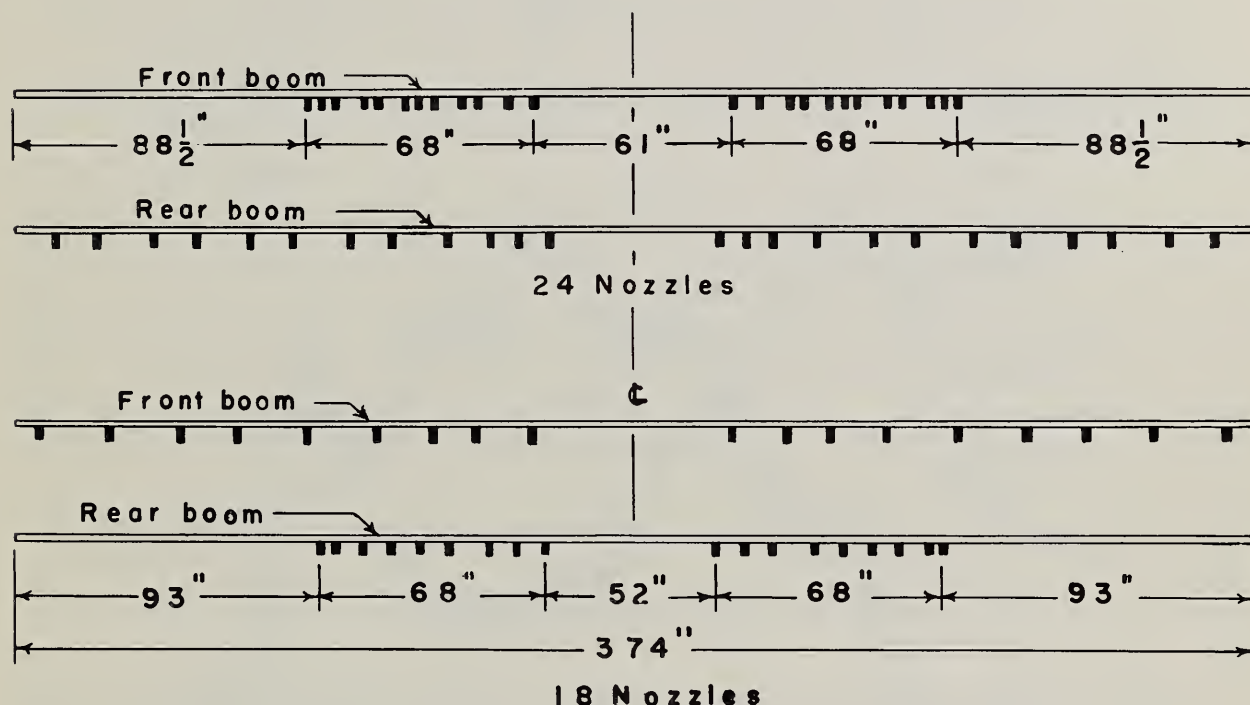


Figure 11 - Nozzle arrangement for flights comparing spray deposit from inboard half with that from standard boom.

Tests with 24 nozzles.--The swath pattern for the flight shown in figure 12 is representative of the four flights with 24 nozzles. The average width of swath at various deposit levels for the four flights was as follows:

<u>Deposit level</u>	<u>Swath width (feet)^{1/}</u>	
<u>g.p.a.</u>	<u>Inboard half of boom</u>	<u>Standard boom</u>
0.1	175	162
.2	146	140
.3	128	118
.4	110	104
.5	94	95

^{1/} Distance over which deposit level was not less than that given in the left column.

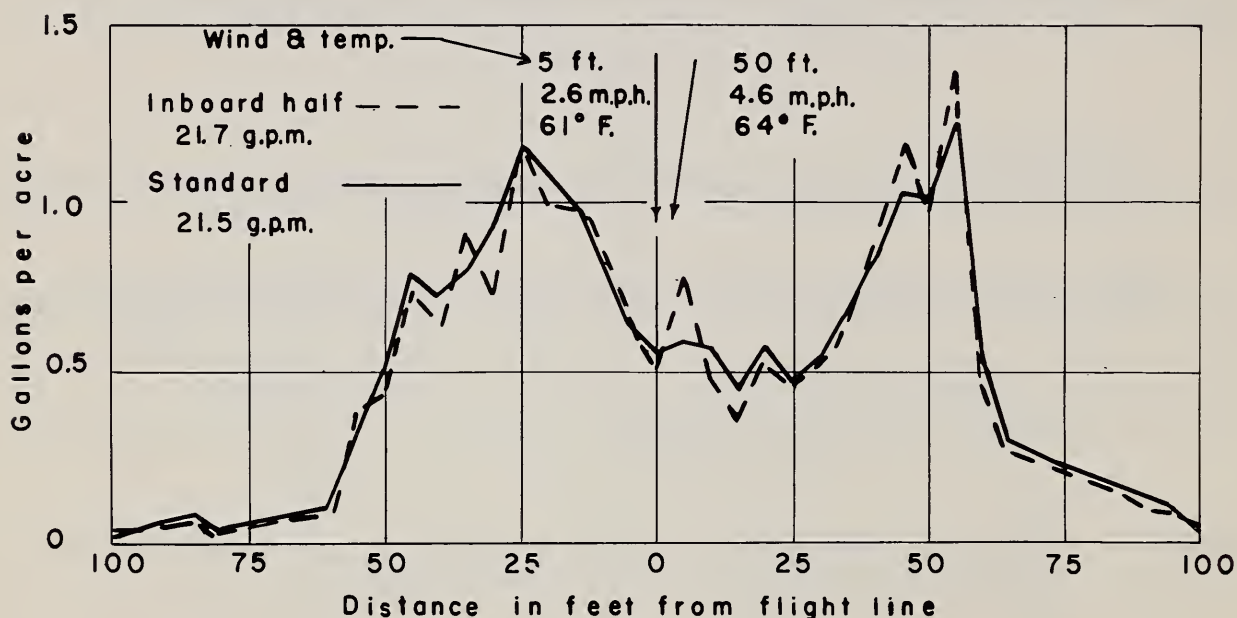


Figure 12 - Spray distribution from inboard half and standard nozzle arrangements: 24 nozzles.

The average recovery was 78 percent for the inboard half and 74 percent for the standard arrangement.

From a practical standpoint there was no difference in the two swath patterns. Although the inboard half arrangement produced a slightly wider swath, the difference was small and was probably due to the slightly higher flow rate from that boom and the inherent variation caused by the turbulent airflow.

Tests with 18 nozzles.--Spray distribution from one of two flights in the tests with 18 nozzles is shown in figure 13. There was very little difference in the spray deposit pattern whether the nozzles were located along the inboard half of the boom or along the full length of the boom. However, the peaks of deposit were somewhat greater from the standard arrangement than from the inboard half arrangement. The reason for this is not clear. It may have resulted from a greater percentage of the spray being moved laterally by the standard arrangement, so that it was drawn into the wingtip vortices and deposited in the peaks. The flow rate was about 6 percent higher from the standard arrangement than from the inboard half. This may also have contributed to the higher peaks.

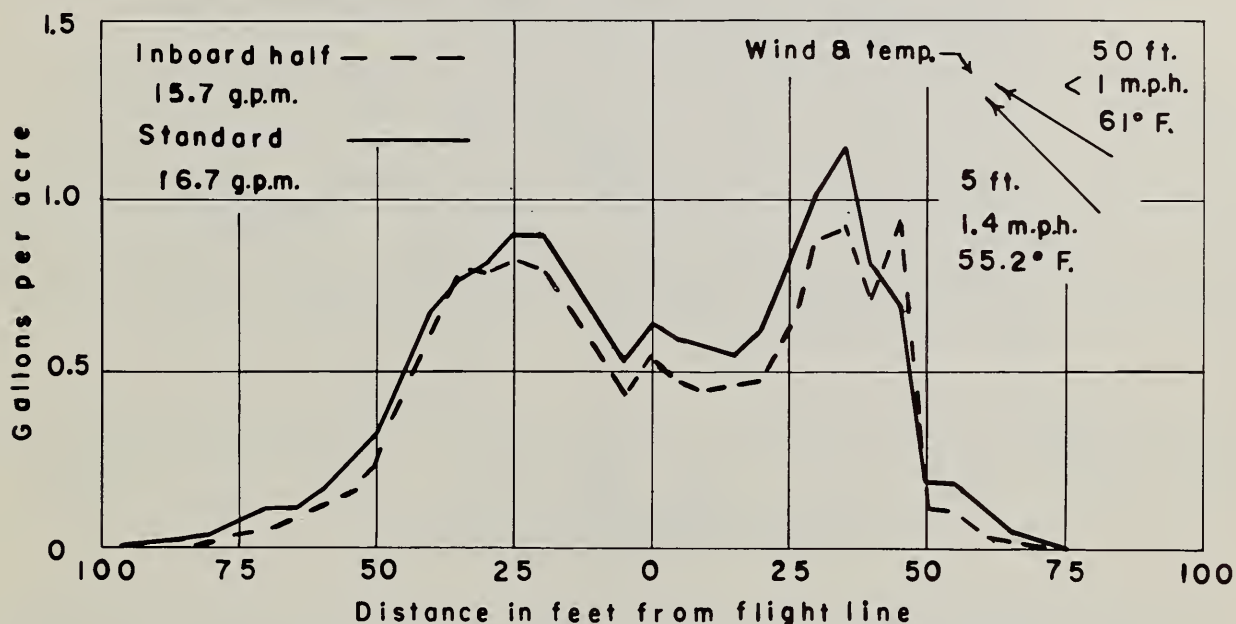


Figure 13 - Spray distribution from inboard half and standard nozzle arrangements: 18 nozzles.

The average width of swath at various deposit levels for the two flights was as follows:

<u>Deposit level</u>	<u>Swath width (feet)^{1/}</u>	
<u>g.p.a.</u>	<u>Inboard half</u>	<u>Standard</u>
	<u>of boom</u>	<u>boom</u>
0.1	115	126
.2	97	101
.3	94	95
.4	91	92
.5	74	90

^{1/} Distance over which deposit level was not less than that given in the left column.

On the average, the standard arrangement produced slightly greater swath widths but these differences were not significant.

Recovery averaged 80 percent from the standard arrangement and 72 from the inboard half.

In summary, the inboard half arrangement resulted in slightly greater swath width and percentage of recovery than the standard arrangement in the 24-nozzle tests; but the reverse was true in the 18-nozzle tests. For all practical purposes, there was no difference in the deposit patterns produced by nozzles distributed along the full span boom, or located only in the inboard half of the boom.

Spray deposits from inboard third and standard boom

Since practically no difference was found in spray distributions produced by nozzles spaced along a full wingspan boom or along only the inboard half of the span, it was decided to study the effect on spray distribution of further inboard concentration of nozzles. The arrangement of nozzles for these studies is shown in figure 14. There were 11 nozzles left of center on the rear boom and 13 on the right. The 12 nozzles that were near the center of the fuselage were extended downward approximately 11 inches below the boom to reduce wetting of the fuselage with spray.

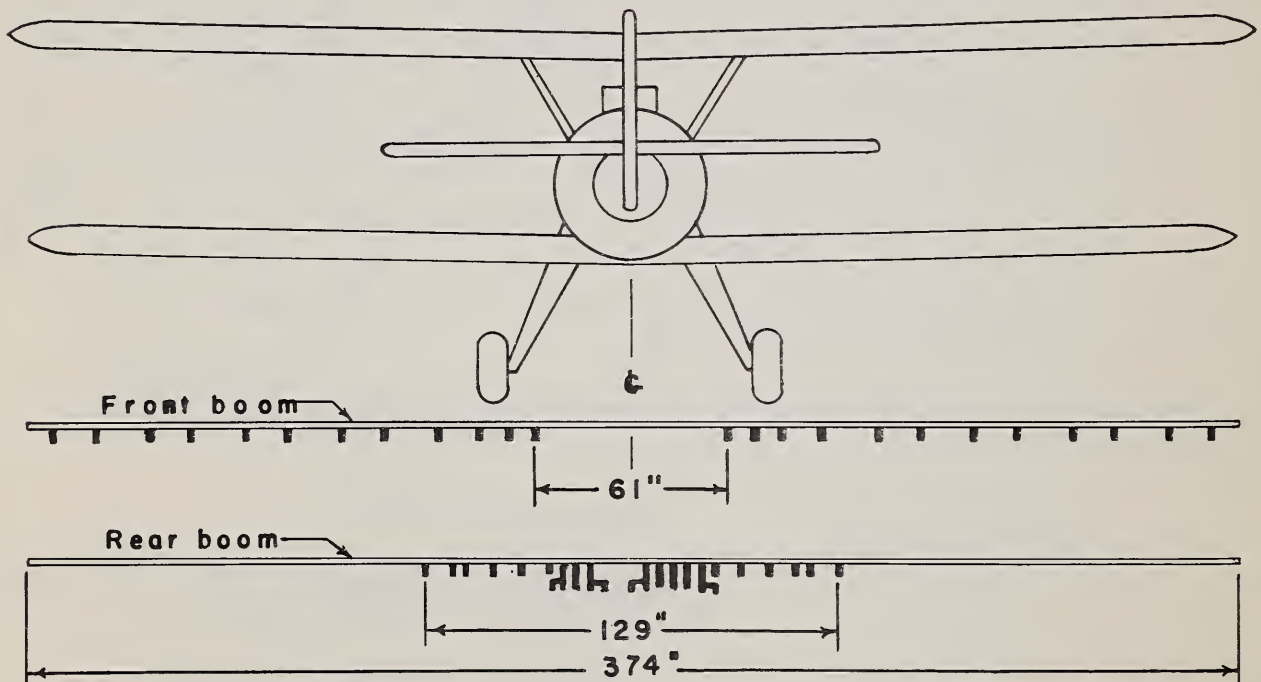


Figure 14 - Nozzle arrangement for flights comparing spray deposit from inboard third with that from standard boom.

Four flights were made in this series. The spray distribution from the flight shown (fig. 15) is typical for all four. The spray released from the inboard third arrangement tended to shift to the left, probably due to torque. Also the peak deposits were lower and the trough (minimum) deposits were higher with the inboard third arrangement as compared to the standard.

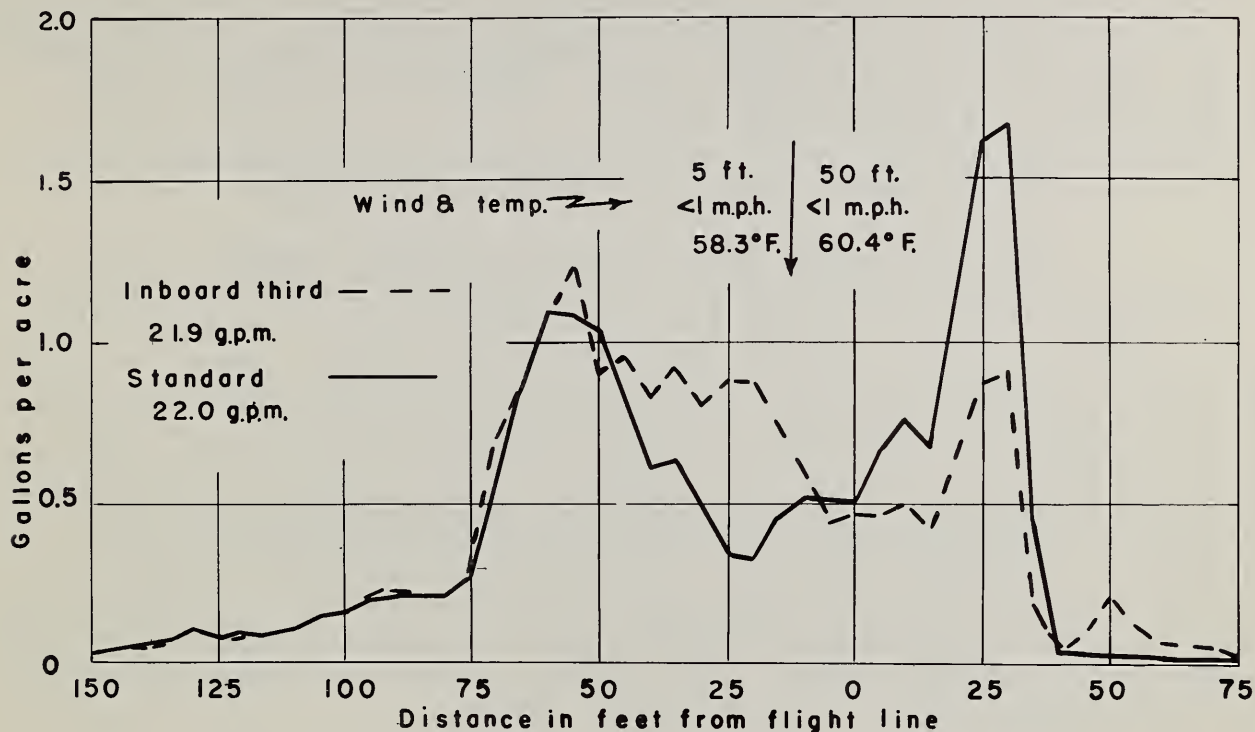


Figure 15 - Spray distribution from inboard third and standard nozzle arrangements.

The average width of swath at various deposit levels for the four flights of this series was as follows:

<u>Deposit level</u>	<u>Swath width (feet)</u> ^{1/}	
<u>g.p.a.</u>	<u>Inboard third</u>	<u>Standard</u>
	<u>of boom</u>	<u>boom</u>
0.1	146	143
.2	120	123
.3	109	111
.4	105	100
.5	93	89

^{1/} Distance over which deposit level was not less than that given in the left column.

No significant differences existed in width of swaths produced by nozzles located in the inboard third of the span, or spaced along the full span.

The average spray recovery from the inboard third arrangement was 76 percent as compared to 80 percent from the standard arrangement. The difference was not significant.

From a practical standpoint the standard arrangement is to be preferred to the inboard third arrangement. The long extensions used for the nozzles located under the fuselage for the latter arrangement resulted in some wetting of the tail wheel by the spray.

Spray deposits from flow rates of 16.7 g.p.m.

(100-foot swath) and 21.4 g.p.m. (132-foot swath)

A study was made to compare deposits produced by flow rates of 16.7 g.p.m. (100-foot swath) and 21.4 g.p.m. (132-foot swath). Here, 18 nozzles were used to produce the lower flow rate and 24 for the higher rate (fig. 16). Two test flights were made and the spray distribution from one of them is shown in figure 17. The peaks of deposit and the troughs or low points in the middle of the swath were higher from the higher flow rate. Study of the deposit curves indicates that the total swath width had not been increased by the higher flow rate. The additional material released was deposited near the center of the swath rather than at the outer edges. The central portion of the swath could also have been filled in by moving some of the nozzles further inboard. The average of the two flights shows the following swath widths at various deposit levels:

<u>Deposit level</u>	<u>Swath width (feet)^{1/}</u>	
<u>g.p.m.</u>	<u>16.7 g.p.m.</u>	<u>21.4 g.p.m.</u>
0.1	132	136
.2	100	108
.3	90	98
.4	74	92
.5	65	80

^{1/} Distance over which deposit level was not less than that given in the left column.

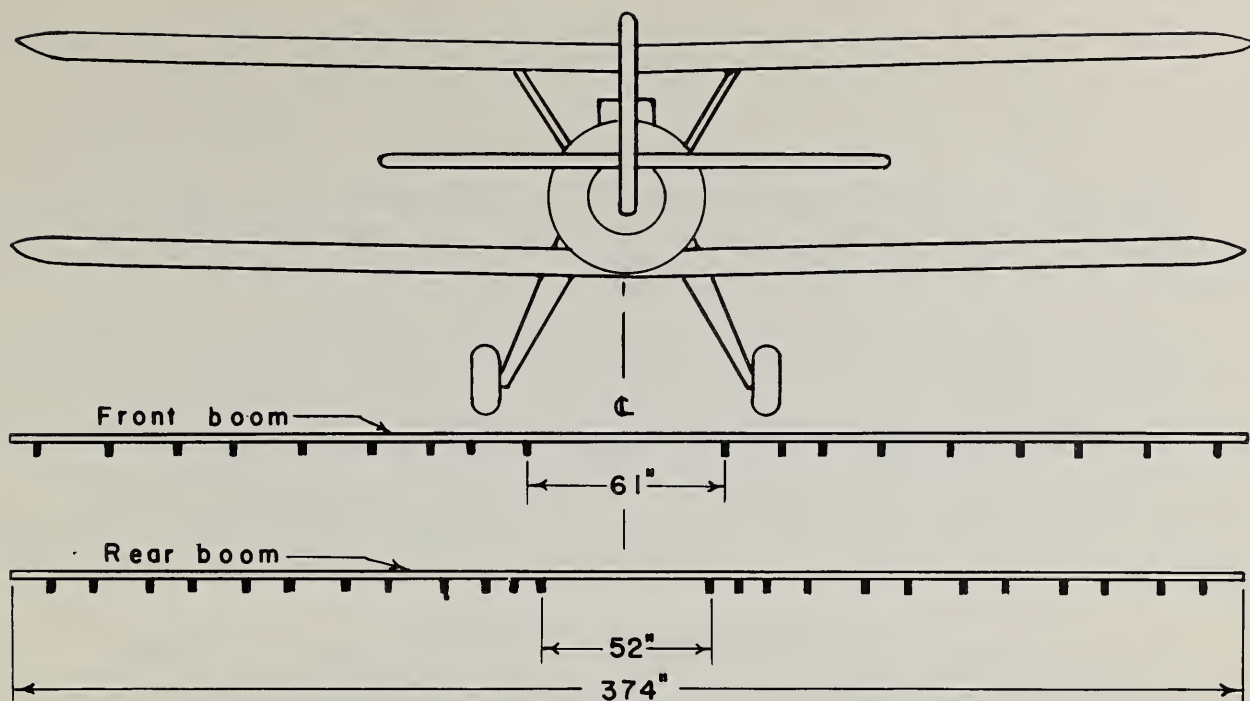


Figure 16 - Nozzle arrangement for flights comparing 16.7 g.p.m. (100-foot swath) with 21.4 g.p.m. (132-foot swath) flow rate.

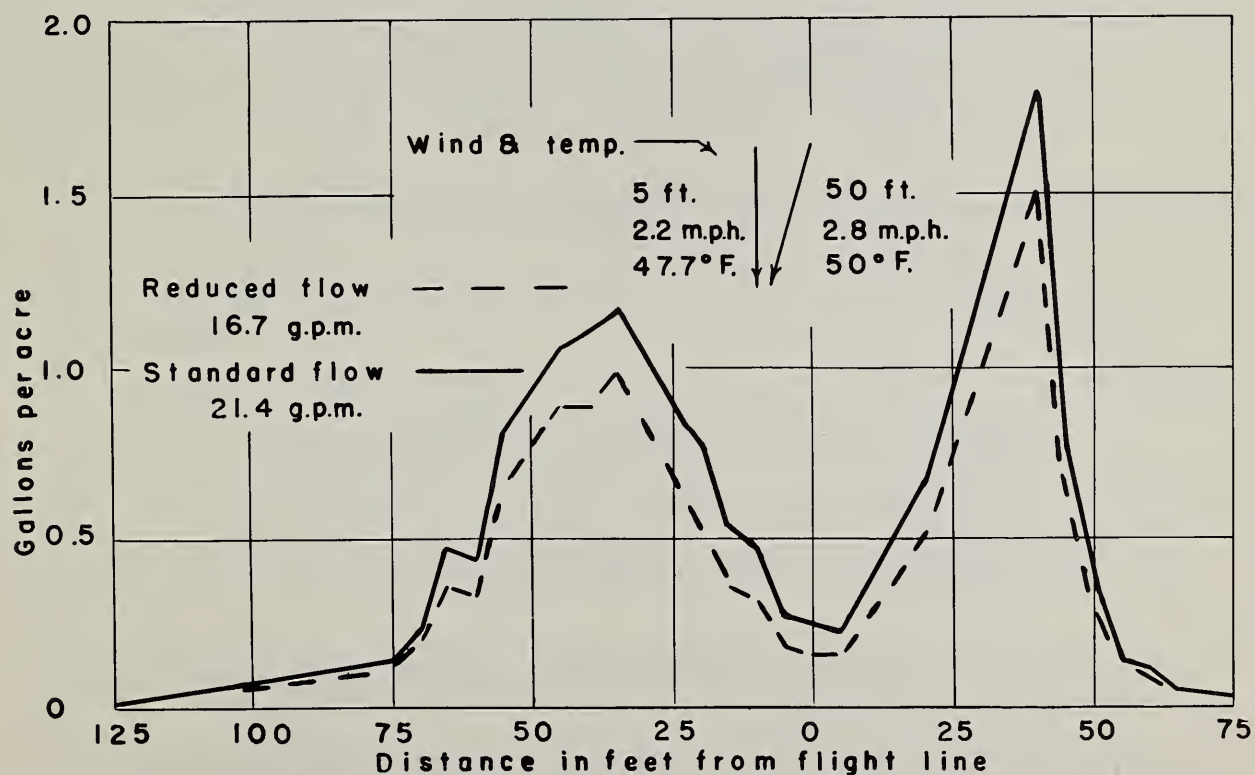


Figure 17 - Spray distribution from reduced and standard flow rates.

The 28-percent higher flow rate increased the swath only 3 to 9 percent at the 0.1 to 0.3 g.p.a. deposit level which is generally effective for control of common defoliators. The swath width increase was considerably greater - 19 to 24 percent - at the 0.4 and 0.5 g.p.a. deposit levels.

There was no appreciable difference in percentage of recovery from the two flow rates; an average of 76 percent was recovered from the lower rate and 74 percent from the higher one.

These results indicate that when applying 1 g.p.a. of spray with a Stearman a swath of 100 feet involves less waste than a swath of 132 feet. They were obtained, however, during upwind flights at 50-foot height. With considerable crosswind, as may occur on most control operations, these results could be markedly different. These studies also suggest that overdosing in the peaks may be reduced by lowering the flow rate and, possibly, the application rate, without appreciably reducing the effective swath.

Typical deposit graph from flights with a Stearman at 50 feet

An average spray deposit pattern developed from 17 selected flights made with a 220-h.p. Stearman is shown in figure 18. These flights were all made with the operating conditions and standard nozzle equipment and arrangement described under Equipment and Procedure and shown in figure 5.

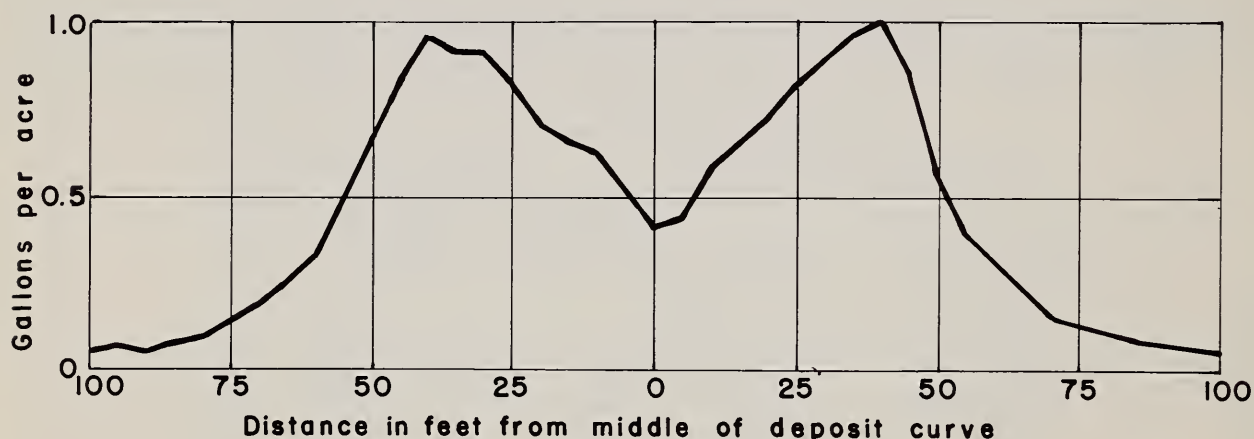


Figure 18 - Average spray distribution from 17 flights with a Stearman.

The deposit graphs for these flights conformed to the following criteria:

1. Not less than 50 feet from trough to short side of swath with a deposit of 0.05 g.p.a.
2. Not more than 0.6 g.p.a. difference between deposit peaks.

3. Between 60 - to 90 - percent spray recovery.

4. Not more than 0.05 g.p.a. deposit at either end of the line.

This graph was plotted by showing distances from the middle of the deposit curve rather than from the flight line. This was done in order to show both the trough, or low point, of the deposit and its peaks, or high points. It shows that on the average when flights are made under conditions similar to those given above, a bimodal deposit pattern results with the peaks of deposit about 40 feet either side of a trough near the center of the swath. This low point may be expected to be about 0.4 g.p.a. and the peaks about 1.0 g.p.a. The graph indicates that there will be swaths of 166 feet at 0.1 g.p.a., 138 feet at 0.2, 124 feet at 0.3, and 114 feet at 0.4 g.p.a. It also indicates no apparent effect of engine torque since the quantity of spray was about evenly divided between left and right sides of the swath. Spray recovery for the 17 flights averaged 76 percent.

SUMMARY AND CONCLUSIONS

These studies show that the aerodynamic forces resulting from an airplane moving through the air have a very marked effect in determining the manner in which sprays are deposited on the ground when they are applied during flights at a height of 50 feet. They show that when nozzles which deliver a spray of medium atomization are arranged along a full span boom on a Stearman airplane a bimodal curve of spray deposit is produced during upwind flights. Finally, they show that (1) heavy peaks of deposit are produced outboard from the wingtips about 40 feet from each side of the flight line, and (2) a low level, or trough, of deposit is produced approximately under the center of the plane.

Several nozzle arrangements were studied with the following results:

1. Distribution of spray released from nozzles on the front boom of a dual sprayer was essentially the same as that released from nozzles on the rear boom.

2. In low level flights with a Stearman, torque affected spray distribution patterns and an asymmetrical nozzle arrangement was used to compensate for it (Chamberlin, et al., 1955). At the greater spraying height employed in the present study the effect of torque was apparently obscured by other factors. Therefore no compensating arrangement was needed.

3. Distribution of spray from nozzles on the left and right halves of a boom was essentially alike.

4. Spray distribution from nozzles (a) along the full wingspan and (b) only along the inboard half of the wingspan, was almost identically the same.

5. Concentrating the nozzles near the wingtips accentuated the deposit peaks without appreciably increasing the total swath.

6. Concentrating the nozzles near the center of the wingspan reduced the deposit peaks and there was no significant difference in width of swath between this arrangement and the full span arrangement. With the inboard third concentration, however, there was some wetting of the tail wheel by spray from the nozzles directly under the fuselage.

7. Deposit peaks were reduced appreciably by using a full span boom and reducing the flow rate from 21 g.p.m. to 16 g.p.m. This caused a decrease of only about 8 percent in the widths of swaths at 0.2 to 0.3 g.p.a. deposit levels. This indicates that there will be more waste of spray, due to overdosing in the peaks, when 1 g.p.a. is applied in a 132-foot swath than when applied in a 100-foot swath. These studies also suggest the possibility of reducing the flow rate still further without reducing the allowable swath width because of the tendency for spray to be deposited in the bimodal peaks in excess of that required for effective control.

8. Based on an average of 17 selected upwind flights, 76 percent of the spray released from the plane was recovered on the ground, as measured by the dye tracer method. Discharging spray at the rate of 1 g.p.a. over a 132-foot swath resulted in average swath widths of 166 feet, 138 feet, and 124 feet at deposit levels of 0.1, 0.2, and 0.3 g.p.a. respectively.

RECOMMENDATIONS

Recommendations based on the results of this study and observations in the field apply for a Stearman or similar airplane when spraying forests under the following general conditions:

1. Application rates up to 1 g.p.a. of a conventional oil base insecticide.
2. Medium spray atomization of approximately 150 microns m.m.d.
3. Flying height greater than 50 feet above the trees.

The recommendations are as follows:

1. Adjust flow rate to cover an effective swath of 100 feet.
2. Space flight lines 100 feet apart.
3. Space nozzles evenly over a one-half to full wing span boom.
4. Do not mount nozzles directly beneath the fuselage.